Computational Fluid Dynamics, Not Crystal Balls, Help in Predicting the Future at Marshall Space Flight Center

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For centuries, mankind has sought to predict the future, but at MSFC, its computers, not crystal balls, and mathematics, not magic, are helping rocket scientists predict successful designs of future American spacecraft and propulsion systems.

The Computational Fluid Dynamics (CFD) Branch, led by Dr. Paul K. McConnaughey, is part of the Fluid Dynamics Division of the Structures and Dynamics Laboratory at MSFC. Using both desktop computer work stations and the Cray supercomputer at the Marshall Center, the men and women in the CFD branch use a variety of software to model the flow of liquids and gasses critical to the design and development of current and future spacecraft and propulsion systems. Both liquids and gases are considered fluids for the purpose of computational analysis of their dynamic properties.

McConnaughey said, “CFD is an analytical tool which helps speed design and guide development while reducing costs and saving time. CFD does not replace wind tunnel testing of aerodynamic designs or ‘hot firing’ of rocket engines. It does help to make such activities more time- and cost-effective through early identification of probable ‘dead-end’ designs, mathematical evaluation of alternative approaches to problem solving, and appreciation of potential improvements early in the design process. CFD enables us to look at design options up front, early in a program’s development, ensuring NASA and NASA-contractor engineers identify and pursue optimum solutions in the most efficient way possible.”

The branch has initiated work on the X–33 and X–34 spacecraft with which NASA hopes to replace its current fleet of Space Shuttles in the next century.

“We’re beginning work on mathematically modeling both the propulsion system and the vehicle itself,” McConnaughey said. “This will be the largest, most complex task ever undertaken by the CFD branch. We’re seeking to understand how various spacecraft shapes will behave operating in the Earth’s atmosphere at high speeds where the gases which comprise the atmosphere ionize around the surface of the craft. Since NASA plans to use a hybrid propellant system—a solid fuel and a liquid oxidizer—we must ensure we fully understand the fluid mechanics and dynamics of candidate fuels and oxidizers, both as liquids on their way to combustion and as gasses during and after combustion in the rocket nozzles. We also are seeking to understand the effect of the thrust of the hybrid engines on the body of the vehicle, particularly on the couplings which hold the engines to the spacecraft. We will provide our mathematical models to materials scientists, engineers and others as we combine our efforts to develop a safe, efficient hybrid propulsion system.”

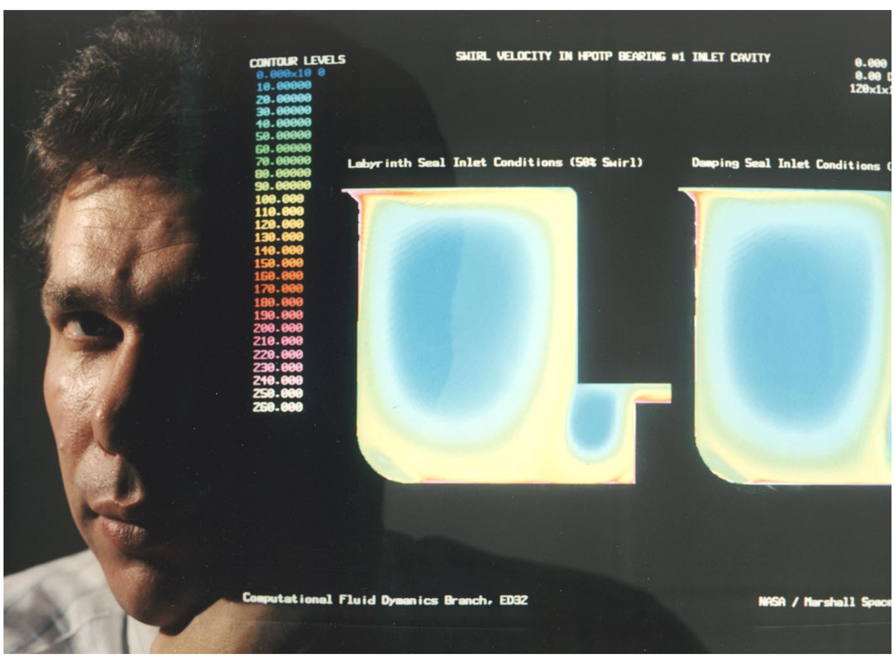

Figure 200.—Dr. Paul McConnaughey was a RTOP award winner with the implementation of state-of-the-art CFD codes at MSFC.

The CFD figures also will be used to assess the impact of hybrid-propellant engine testing and operation on the environment. As an example, McConnaughey told of a study which involved disposing of liquid nitrogen. CFD was used to ensure the nitrogen would disperse safely as it evaporated without posing any dangers.

The Marshall Center has been NASA’s principal field center for the development and evaluation of spacecraft propulsion systems since the beginning of the nation’s space program in the 1950’s.

Turning technologies developed through the national space program to the benefit of

FIGURE 201.—An X–33 configuration which may replace NASA's Space Shuttle.

American industries is a major goal of NASA. Data concerning fluid dynamics is already being used in the new marine jet engine being built in Arkansas, and there is work underway to study using liquefied natural gas (LNG) as a fuel for the family car of the future and for commercial transportation systems. Aircraft and helicopters have already been test flown using LNG as a fuel. Other efforts to commercialize NASA technology in which CFD has played a developmental role include a human bone marrow implant, a cleaning nozzle, and a new design for a valve seat.

As regards assisting the Arkansas firm, the CFD branch was called upon to evaluate a proposed improved impeller blade for a medium-sized powerplant. The CFD branch's Robert Garcia used analytical systems to show that the proposed design would not meet desired performance requirements. Garcia and the firm's design team then discussed modifications to the shape of the impeller blades, which Garcia then analyzed via computer. His figures correctly predicted the new design would meet or exceed all the firm's requirements, resulting in the creation of a new product line for the firm. The marine jet-propulsion engine market is dominated by manufacturers in Europe and New Zealand; however, the Arkansas firm feels NASA's assistance will help it to compete successfully in the international market.

Improving impeller technology is particularly important to NASA as these devices are used to move liquid hydrogen and liquid oxygen from the Space Shuttle's external tank to the three main engines at the tail of the orbiter. A substantial improvement in impeller performance could enable the engine system to be modified to reduce weight of the propulsion system, increasing payload-to-orbit capabilities.

The transfer of technologies developed through the U.S. space program to benefit American industries is a responsibility given NASA in the Space Act of 1958 which established the agency. Firms interested in receiving NASA technological assistance to resolve manufacturing problems are encouraged to call 1–800–USA–NASA.

Sponsor: Office of Commercial Development and Technology Transfer

Biographical Sketch: Bob Lessels is the technical writer/editor (physical sciences) for the Technology Transfer Office at the Marshall Center. A graduate of the University of Nebraska, he has been a professional journalist for the past 30 years. He joined NASA in 1986.